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RESEARCH ARTICLE

Effect of Stone Density, Skin-Stone Distance and Stone Size on Extracorporeal Shock Wave Lithotripsy Success of Ureter Stones: A Clinical Investigation

Erhan Erdoğan [1], Fatih Özçelik [2], Gül Kahraman [3], Mihriban Şimsek[4*], Kemal Sarıca [1,5]

[1] Department of Urology, Sancaktepe Training and Research Hospital, University of Health Sciences, Istanbul, Türkiye
[2] Department of Medical Biochemistry, Hamidiye Etfal Training and Research Hospital, University of Health Sciences, Istanbul, Türkiye
[3] Department of Medical Biotechnology, Hacettepe University, Ankara, Türkiye
[4] Department of Medical Biochemistry, Birecik State Hospital, Sanlıurfa, Türkiye
[5] Department of Urology, Biruni University, Medical School, Istanbul, Türkiye

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Corresponding Author;
Mihriban Şimşek, MD
Address: Department of Medical Biochemistry, Birecik State Hospital, Sanlıurfa, Türkiye
E-mail: mihribansimsek106@gmail.com

ORCID
E.E. 0000-0003-0910-5370
F.Ö. 0000-0003-2439-3964
G.K. 0000-0001-8724-8954
M.Ş. 0009-0000-5213-7234
K.S. 0000-0002-2473-1313

Abstract

Objective: This study aimed to investigate the correlation between demographic characteristics, stone size, density, and location, skin-to-stone distance (SSD), urinary parameters, and the success rate of extracorporeal shock wave lithotripsy (ESWL) in patients with ureteral stones.

Material and Methods: A total of 151 patients with ureteral stones were included in this retrospective study, and ESWL treatment was successful in 116 of them. Stone size, density, and ureteral location (upper/lower and right/left) were evaluated using non-contrast computed tomography, and SSD was measured. Demographic characteristics [age, gender, and BMI (Body Mass Index)] and complete urinalysis parameters (pH, specific gravity, protein, leukocytes, erythrocytes, casts, and various crystal types) were recorded. The impact of these factors on ESWL success was statistically analyzed.

Results: A significant negative correlation was found between ESWL success and stone density [in Hounsfield units (HU)], SSD, and patient age. Treatment success was lower for hard stones (HU ≥ 1000) compared to soft stones (HU < 1000) (ESWL successful: 28/45 (62%) vs 88/106 (83%), p = 0.006). Similarly, patients with successful ESWL had lower ages and SSD compared to those with unsuccessful outcomes (41±13 vs 45±9 years and 117±18 vs 125±17 mm, respectively). Additionally, stones with higher density were found to be larger compared to those with lower density, with a low-level positive correlation (9.0(4.8-15.0) vs 7.8(4.2-15.0) mm, p=0.0458; r=0.240, p=0.0029). Binary regression analysis revealed that SSD, stone density (HU), and stone location significantly influenced ESWL success and could predict outcomes with 78.8% accuracy (p=0.005, 0.002, and 0.014, respectively).

Conclusion: Increased stone density, longer SSD, and advanced age can decrease the success of ESWL treatment. This study highlights the importance of considering these variables when planning ESWL treatment.

Keywords: age, ESWL successful, skin-stone distance, stone density (HU)

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INTRODUCTION

Urolithiasis that causes serious health problems, is a condition characterized by the formation of crystal agglomerates in the urinary tract and its incidence is increasing worldwide. Many factors, including age, gender, occupation, climate, systemic disease, diabetes, vascular disease, chronic kidney disease, diet and ethnicity, affect the prevalence and incidence of urolithiasis. It also causes pain, urinary tract infections and kidney dysfunction, limiting individuals' daily life activities, making it difficult to participate in the workforce and increasing the social financial burden (1–6).

Among the various methods used in the treatment of urolithiasis, Extracorporeal Shock Wave Lithotripsy (ESWL) stands out as a non-invasive option. While ESWL breaks stones with shock waves and allows them to be expelled from the body, its success varies depending on many factors. Many variables such as the physical properties of the stone, the anatomical structure of the patient and biochemical parameters have been found to be directly related to the success of ESWL (7–9). Therefore, being able to predict the results of ESWL treatment is important in terms of the management and treatment planning of patients with these variables.

Recent studies have shown that smaller stone size, younger patient age, and shorter skin-stone distance (SSD) are the most important factors predicting ESWL success. In addition, the composition and density of the stone, measured in Hounsfield Units (HU), have been reported to affect the efficiency of stone fragmentation, with denser stones being more resistant to treatment (10–13). However, further studies are needed on this subject.

This study aims to contribute to the literature by investigating a wider range of factors beyond the commonly studied factors (stone size, age, SSD) that may influence ESWL success. By including demographic characteristics [age, gender, BMI (Body Mass Index)], urine parameters (such as pH, density, protein, leukocytes, erythrocytes, casts and various crystal types) and stone density (in HU), potentially new predictors can be identified.

By considering this wider range of factors, this study may contribute to the adoption of a more personalized approach to the treatment of urolithiasis, contributing to the literature with better patient outcomes and potentially reduced healthcare costs.

MATERIAL AND METHODS

Design of Working Groups and Inclusion Criteria

The study that was conducted as a single-center analytical cross-sectional retrospective study, examined approximately 450 patients who came to the Sancaktepe Education and Research Hospital urology clinic with suspicion of urolithiasis between June 2023 and June 2024. Patients with ureteral stones detected by Non-Contrast Computed Tomography (NCCT) and complete clinical data were selected for the study. Of these patients, 151 patients who had an indication for ESWL treatment due to ureteral stones were included in the study. The density of the stones was measured in HU. Demographic characteristics (age, gender, BMI), symptoms [renal colic, oliguria/anuria, nausea and vomiting, dysuria, difficulty urinating, pollakiuria, fever and chills, and costovertebral angle (CVA) tenderness (CVAT)] and urine examination findings [hematuria, urine color, urine odor, density, pH, erythrocytes, leukocytes, casts, protein, calcium oxalate monohydrate (COM) or calcium oxalate dihydrate (COD) crystals, Struvite crystals, amorphous urate crystals, amorphous phosphate crystals] were recorded. In addition, patients were questioned about physical inactivity, oral contraceptives (OCs) use, and comorbidity status (hypertension, diabetes, metabolic syndrome, obesity, chronic kidney disease, cardiovascular diseases, gout, hyperlipidemia, inflammatory bowel disease, osteoporosis, malignancy, thyroid disease, uric acid metabolism disorder, and hypercoagulability, etc.). Those included in the study groups were divided into 2 groups according to the success of ESWL treatment, 116 of them were successful in treatment, while 35 patients were unsuccessful.

Exclusion Criteria

Those who were younger than 18 or older than 70 years, those with urinary tract infection, those who were pregnant, those who had undergone surgery before treatment, those with chronic renal failure, those with coagulopathy, those with stones >20 mm or <5 mm [In the treatment planning of patients in our study, the recommendations of the EAU (European Association of Urology) guidelines were considered. URS was regarded as the first-line treatment option for ureteral stones larger than 10 mm. However, in accordance with the practice protocol of our center, patients were evaluated for ESWL feasibility rather than undergoing URS. Patients included in this study had not undergone URS previously and were directly assessed for ESWL treatment.], those with anatomical anomalies in the kidney, those with serious cardiac disease, patients with a single kidney, those with a stent inserted in the urinary system, those who were noncompliant with treatment or did not come for follow-up were excluded from the study.

Stone Density (HU) Measurement

Stone density of each patient was measured in HU on NCCT images (Canon, Aquilion Lightning 16, Japan). Images were obtained using the same standards [2 mm slice thickness, 120 kVp, 200 mA]. The site of the ureteral calculi was identified by the radiologist and the density of the stone was measured. Using radiology software for measurement, HU values were obtained from at least 3 different points from the center of the stone and the mean density of the stone was determined by calculating the average of these values.

ESWL Treatment Protocol

Patient Selection: Patients who were diagnosed with ureterolithiasis by NCCT or ultrasound and who were eligible for ESWL according to stone size (5 - 20 mm), localization (stones located in the upper and lower part of the ureter) and HU values were treated with ESWL. The stone density was measured by HU values. Stones below 1000 HU could be easily fragmented by ESWL, while stones with high density above 1000 HU were predicted to be more resistant to treatment.

Preoperative Evaluation: Laboratory tests including complete blood count, coagulation parameters, urinalysis and urine culture were performed before treatment. Patients with active urinary infection were enrolled in ESWL procedure after controlling with antibiotic treatment. During treatment, patients were hospitalized in supine position. To provide pain control during ESWL, 75 mg diclofenac potassium was administered intramuscular half an hour before the procedure.

Modulith SLK inline lithotripter [Storz Medical, Switzerland] was used in ESWL treatment. The treatment was performed by applying a maximum of 4000 shock waves at a frequency of 60-90 shocks/minute in each session. The energy level of the shock waves was initially set between 0.5-1.0 mJ/mm² and gradually increased up to 2.0-3.0 mJ/mm² according to the characteristics of the stone and the patient. Fluoroscopy was used for stone localization and ultrasonography was used for radiolucent stones. If no complications developed after ESWL treatment, the next session was scheduled 7 days later. A total of 3 sessions were performed and treatment response was evaluated at each session.

Post-Treatment Follow-up: After ESWL treatment, patients were followed up clinically to evaluate renal function. NCCT was performed 3 months after treatment to evaluate treatment success. Stone-free or stone fragmentation ≤4 mm on post-treatment imaging was considered as a criterion for treatment success. Post-treatment complications such as hematuria, severe renal pain, urinary infection or stone obstruction were controlled.

Ethical Approval for this study was obtained from the Sancaktepe Training and Research Hospital Clinical Research Ethics Committee (Decision No: 2024/298, dated 24.09.2024, numbered E-46059653-050.99-254458275). All patients participating in the study were informed about the study and their informed consent was obtained.

Statistical Analysis

IBM SPSS Statistic Software program (Version-27, Chicago, USA) was used for processing the data obtained from the study and for statistical evaluation. Kolmogorov Smirnov test was used for normality test of the data. Chi square test was applied for evaluation of categorical data. Student t test and Mann-Whitney test were used for comparison of parametric and non-parametric data of two groups, respectively. Pearson correlation analysis and Spearman correlation analysis were performed for examination of the relationship between parametric and non-parametric data of independent variables, respectively. Binary logistic regression analysis was applied using independent variables consisting of age, lower/upper localization, SSD, stone density and stone size, which are thought to influence ESWL success. Bar chart and box plots graphics were used for presentation of non-parametric data.

Power Analysis of the Study

In order to determine the minimum number of subjects required for this study, a priori power analysis (G-Power version 3.1, Germany) was performed based on the data of a study investigating the factors affecting the outcome of ESWL in the treatment of urinary stones (14). As a result of this analysis, it was calculated that at least 18 experimental subjects (ESWL successful) and 18 independent controls (ESWL unsuccessful) were required for urolithiasis stone density (effect size d = 1.01, α = 0.05, power = 0.90). However, since each group should consist of at least 30 subjects to achieve a stronger prediction and parametric statistical analyses, the number of ESWL successful groups was determined as 116 and the number of ESWL unsuccessful groups as 35.

RESULTS

Comparison of Demographic and Clinical Characteristics

When the demographic characteristics of the study groups were analyzed (Table 1), while there were no statistical differences between the groups in terms of gender and BMI (p=0.156 and p=0.2011, respectively), the age of the patients in the unsuccess group was higher compared to the success group (p=0.0458). There was no difference between the groups in terms of symptoms (renal colic, oliguria or anuria, nausea and vomiting, dysuria, difficulty urinating, pollakiuria, fever and chills, and CVAT) and comorbidities (p>0.05). Although there was no statistical difference between the groups in terms of upper/lower and right/left (R/L) localization and stone size (p=0.805, p=0.065 and p=0.7126), the stones of the success group tended to be on the right compared to the unsuccess group (Table 2). Stone density was higher, and SSD was longer in the unsuccessful group (p=0.0059 and p=0.0288). Urine specific gravity (u-SG), urine pH (u-pH), urine protein (u-Pr), urine red blood cell (u-RBC), urine white blood cell (u-WBC), Casts, urine amorphous urate crystals (u-AUC), urine amorphous phosphate crystals (u-APC), urine struvite crystals (u-SC), urine calcium oxalate monohydrate crystals (u-COM) and urine calcium oxalate dihydrate crystals (u-COD) did not differ between the groups (p>0.05).

Table 1. Comparison of demographic and clinical data of urolithiasis study groups according to the success of ESWL treatment

	Success Group	Unsuccess Group	p value
n	116	35	-
Gender, M (%)	90(78%)	23(66%)	[c] 0.156
Mean Age ± SD (year) Median Age (min-max) (year)	41±13 38(17-73)	45±9 47(26-60)	[b] 0.0458
Mean BMI±SD (kg/m^2) Median BMI (min-max) (kg/m^2)	27±4 27(18-40)	28±4 28(21-40)	[b] 0.2011
Renal colic, n(%)	81(70%)	20(57%)	[c] 0.162
Dysuria, n(%)	17(15%)	9(26%)	[c] 0.129
Difficulty in urination, n(%)	17(15%)	9(26%)	[c] 0.129
Oliguria/Anuria, n(%)	3(3%)	0	[c] 0.337
Pollakiuria, n(%)	15(13%)	9(26%)	[c] 0.070
Fever and chills, n(%)	6(5%)	3(9%)	[c] 0.433
Nausea and vomiting, n(%)	21(18%)	5(14%)	[c] 0.645
CVAT, n(%)	6(5%)	3(9%)	[c] 0.436
Comorbidities, n(%)	49(42%)	14(40%)	[c] 0.814

b Independent sample t test, c Chi-Square test.
Statistical significance level is p<0.05.
Parametric data were given as mean ± standard deviation and nonparametric data were given as median (min-max).
ESWL: Extracorporeal Shock Wave Lithotripsy **M:** Male, **BMI:** Body mass index, **CVAT:** Costovertebral angle tenderness, **SD=** Standard Deviation, **min:** minimum, max: maximum, **n:** Number

Table 2. Comparison of radiological and laboratory data of urolithiasis study groups according to the success of ESWL treatment

	Success Group	Unsuccess Group	p value
n,	116	35	-
Lower/Upper, n(%)	47(%41)/69(%59)	15(%43)/20(%57)	[c] 0.805
Right/Left, n(%)	57(49%)/59(51%)	11(31%)/24(69%)	[c] 0.065
Mean stone size ± *SD*, mm Median stone size (min-max), mm	8.3±2.3 7.8(4,2-15.0)	8.6±2.6 8.8(4.2-15.0)	[a] 0.7126
Mean stone density ± *SD*, HU Median stone density (min-max), HU	808±265 781(295-1517)	964±360 987(326-1781)	[b] 0.0059
Mean SSD ± *SD*, mm Median SSD (min-max), mm	117±18 117(66-173)	125±17 124(87-168)	[b] 0.0288
Mean u-SG ± *SD* Median u-SG (min-max)	1018±7 1017(1002-1055)	1018±10 1018(1002-1055)	[b] 0.7077
Mean u-pH ± *SD* Median u-pH (min-max)	6.3±0.5 6.0(5.5-8.0)	6.3±0.4 6.0(5.5-7.5)	[a] 0.3842
u-Pr, n(%)	25(22%)	5(14%)	[c] 0.460
u-RBC, n(%)	93(80%)	27(77%)	[c] 0.857
u-WBC, n(%)	75(52%)	20(30%)	[c] 0.420
Casts, n(%)	5(4%)	2(6%)	[c] 0.663
u-AUC, n(%)	12(10%)	3(9%)	[c] 0.759
u-APC, n(%)	9(8%)	6(17%)	[c] 0.115
u-SC, n(%)	4(3%)	1(3%)	[c] 1.000
u-COM, n(%)	7(6%)	3(9%)	[c] 0,698
u-COD, n(%)	8(7%)	2(%6)	[c] 1.000

a Mann-Whitney U Test, b Independent sample t test, c Chi-Square test. Statistical significance level is p<0.05.
Parametric data were given as mean ± standard deviation and nonparametric data were given as median (min-max).
ESWL: Extracorporeal Shock Wave Lithotripsy, **HU**: Hounsfield Units, **SSD:** Skin-to-stone distance, **u-SG:** Urine specific gravity, **u-pH:** Urine pH, **u-RBC:** Urine red blood cell, **u-WBC:** Urine white blood cell, **u-Pr:** urine protein, **u-AUC:** Urine amorphous urate crystals, **u-APC:** Urine amorphous phosphate crystals, **u-SC:** Urine struvite crystals, **u-COM:** Urine calcium oxalate monohydrate crystals, **u-COD:** Urine calcium oxalate dihydrate crystals, **SD** = Standard Deviation, **min:** minimum, **max:** maximum, **n;** Number

When HU<1000 and HU≥1000 groups formed according to stone density were examined (Table 3), no statistical difference was found between the groups in terms of R/L localization, SSD, u-SG, u-PH, u-Pr, u-RBC, u-WBC, Casts, u-AUC, u-APC, u-SC(p>0.05). The HU <1000 group had smaller stone size (p=0.0458) (Table 3) and higher ESWL success (p=0.006) (Figure 1A). Again, compared to the HU <1000 group, stones in the HU ≥1000 group tended to be located in the upper ureter (p=0.019) (Figure 1B) and the stone size tended to be larger (p=0.0458) (Table 3). The incidence of u-COD crystal was higher in the HU<1000 group, while u-COM crystal was higher in the HU≥1000 group (p=0.033 and p=0.001, respectively) (Figure 2A and B).

When SSD ≤110 and SSD >110 groups formed according to SSD were analyzed in terms of ESWL success, it was found that the SSD ≤110 group had a higher success rate (90% vs 71%, respectively, p=0.001) (Figure 3).

Correlation and Regression Analysis

According to the results of correlation analysis, there was no statistically significant correlation between stone size and SSD and u-pH (Spearman r (rs) = -0.035, p = 0.6715 and rs = 0.101, p = 0.2126, respectively). However, there was a low but significant correlation between stone size and stone density (Pearson r = 0.240 p = 0.0029) (Figure 4). In addition, there was no statistically significant correlation between stone density and SSD and u-pH, nor between SSD and u-pH (p>0.05).

Table 3. Comparison of radiological and laboratory data of urolithiasis study groups according to stone density

	Stone Density		
	HU < 1000 (Soft Stones)	**HU ≥ 1000 (Hard Stones)**	**p value**
n,	106	45	-
Upper/Low, n(%)	56(53%)/50(47%)	33(73%)/12(27%)	[c] 0.019
Right/Left, n(%)	45(42%)/61(58%)	23(51%)/22(49%)	[c] 0.328
Stone size, mm	8.2±2.3 7.8(4.2-15.0)	9.0±2.6 9.0(4.8-15.0)	[a] 0.0458
ESWL successful, n	88(83%)	28(62%)	[c] 0.006
Mean SSD ± *SD*, mm Median SSD (min-max), mm	120±20 119(66-173)	117±13 119(88-144)	[b] 0.3677
Mean u-SG ± *SD* Median u-SG (min-max)	1018±7 1019(1004±1033)	1018±8 1017(1002-1055)	[b] 0.9111
Mean u-pH ± *SD* Median u-pH (min-max)	6.3±0.5 6.0(5.5-8.0)	6.2±0.5 6.0(5.5-7.5)	[a] 0.2076
u-Pr, n(%)	18(17%)	10(22%)	[c] 0.448
u-RBC, n(%)	83(78%)	37(82%)	[c] 0.686
u-WBC, n(%)	69(65%)	26(58%)	[c] 0.395
Casts, n(%)	5(4%)	2(6%)	[c] 0.942
u-AUC, n(%)	10(9%)	5(11%)	[c] 0.770
u-APC, n(%)	11(10%)	4(9%)	[c] 0.780
u-SC, n(%)	5(5%)	0(0%)	[c] 0.312
u-COM, n(%)	2(2%)	8(18%)	[c] 0.001
u-COD, n(%)	10(9%)	0(0%)	[c] 0.033

a Mann-Whitney U Test, b Independent sample t test, c Chi-Square test. Statistical significance level is $p<0.05$.
Parametric data were given as mean ± standard deviation and nonparametric data were given as median (min-max).
ESWL: Extracorporeal Shock Wave Lithotripsy, **HU:** Hounsfield Units, **SSD:** Skin-to-stone distance, **u-SG:** Urine specific gravity, **u-pH:** Urine pH, **u-RBC:** Urine red blood cell, **u-WBC:** Urine white blood cell, **u-Pr:** urine protein, **u-AUC:** Urine amorphous urate crystals, **u-APC:** Urine amorphous phosphate crystals, **u-SC:** Urine struvite crystals, **u-COM:** Urine calcium oxalate monohydrate crystals, **u-COD**: Urine calcium oxalate dihydrate crystals, **SD** = Standard Deviation, **min:** minimum, **max:** maximum, **n;** Number

Table 4. Binary logistic regression analysis results applied to determine the effect of five independent variables on ESWL success

Variable	**b**	**SE**	**OR**	**95% CI**		**p**
				LL	**UL**	
Constant	9,006	2,159	8149,664			0,000
Age	-0,032	0,019	0,968	0,934	1,004	0,084
SSD	-0,032	0,012	0,969	0,946	0,993	0,012
Stone density (HU)	-0,002	0,001	0,998	0,996	,999	0,002
Stone size	0,016	0,093	1,016	0,846	1,220	0,867
R/L location	-1,062	0,450	0,346	0,143	0,835	0,018

Note. Overall estimate percentage = %79.5 Omnibus Test (Chi-square= 23,287, $p<0.001$), Hosmer and Lemeshow Test (Chi-square= 11,051, p=0.199), Nagelkerke R2=0,216. **ESWL:** Extracorporeal Shock Wave Lithotripsy, **R/L:** Right/Left, **SSD:** Skin-to-stone distance, **HU:** Hounsfield Units, **LL:** Lower Limit, **UL:** Upper Limit

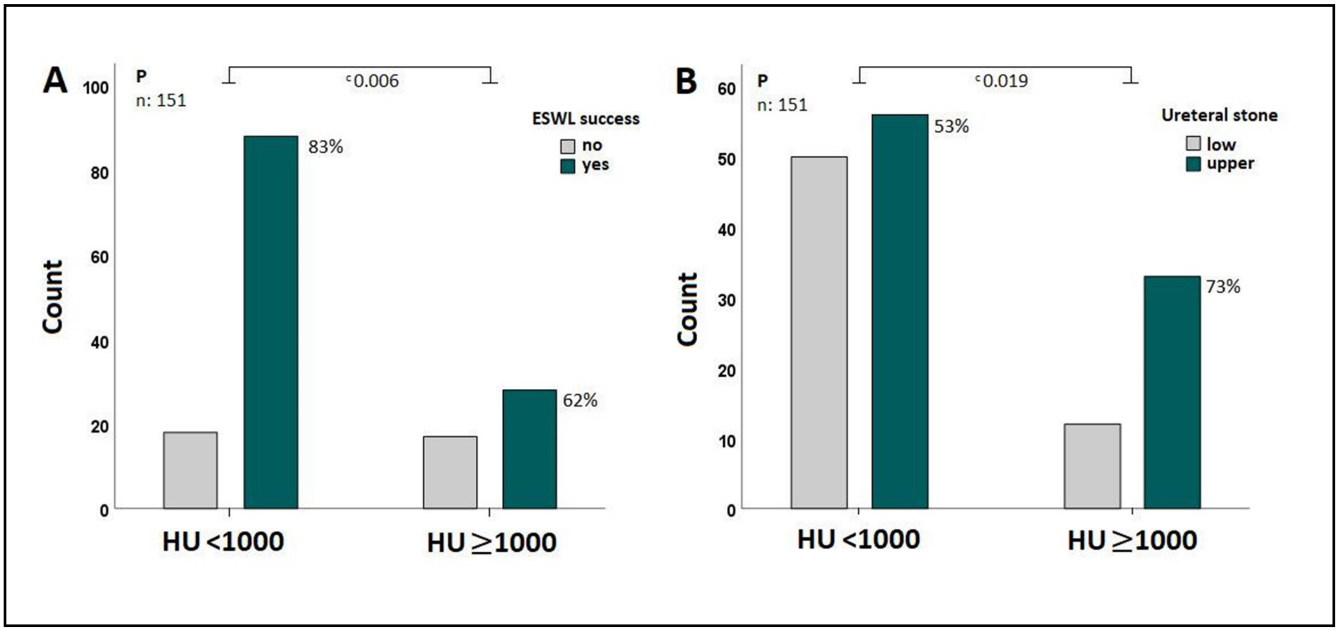

Figure 1. Bar chart showing the comparison of extracorporeal shock wave lithotripsy (ESWL) success (A) and stone localization (right/left side) (B) between the Hounsfield Units (HU) <1000 and HU ≥1000 groups. It is observed that ESWL success is higher in the HU <1000 group. Additionally, stones in the HU ≥1000 group are more frequently located in the upper ureter compared to the HU <1000 group. c Chi-square test.

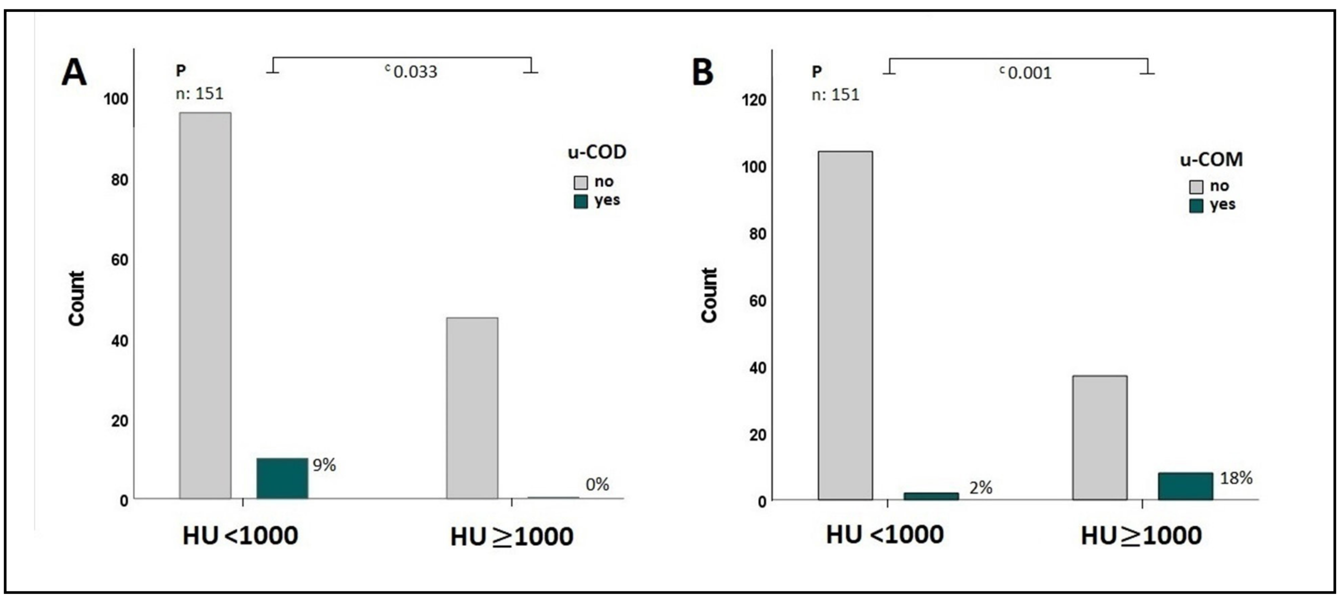

Figure 2. Bar chart displaying the occurrence rates of urine calcium oxalate dihydrate crystals (u-COD) (A) and urine calcium oxalate monohydrate crystals (u-COM) (B) crystals in the Hounsfield Units (HU) <1000 and HU ≥1000 groups. The occurrence rate of u-COD crystals is higher in the HU <1000 group, while u-COM crystals are more frequent in the HU ≥1000 group. c Chi-square test.

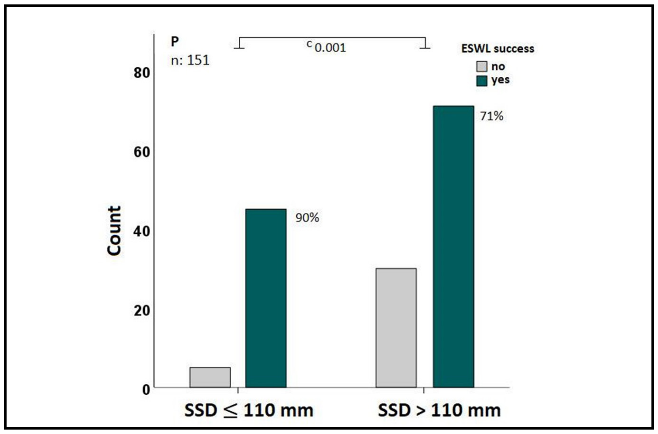

Figure 3. Bar chart illustrating extracorporeal shock wave lithotripsy (ESWL) success rates between skin-to-stone distance (SSD) ≤110 and SSD >110 mm groups based on skin-stone distance (SSD). ESWL success is higher in the SSD ≤110 mm group.

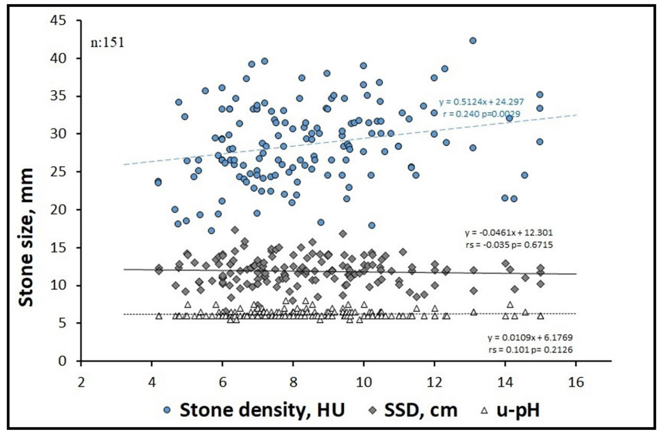

Figure 4. Spearman correlation graph representing the relationship between stone size and skin-to-stone distance (SSD), stone density, and urine pH (u-pH) values across all study groups. According to the correlation analysis, there is no statistically significant correlation between stone size and u-pH or SSD. However, a weak but significant correlation exists between stone size and stone density. rs: Spearman correlation test, r: Pearson correlation test.

Table 5. Binary logistic regression analysis results applied to determine the effect of three independent variables on ESWL success

Variable	b	SE	OR	95% CI		p
				LL	UL	
Constant	8,021	1,902	3044,483			0,000
SSD	-0,035	0,012	0,966	0,943	0,990	0,005
Stone density (HU)	-0,002	0,001	0,998	0,996	0,999	0,002
R/L location	-1,093	0,444	0,335	0,140	0,800	0,014

Note. Overall estimate percentage = %78,8, Omnibus Test (Chi-square= 20.265, p<0.001), Hosmer and Lemeshow Test (Chi-square= 12.849, p=0.117), Nagelkerke R2=0.190, ESWL: Extracorporeal Shock Wave Lithotripsy, R/L: Right/Left, SSD: Skin-to-stone distance, HU: Hounsfield Units, LL: Lower Limit, UL: Upper Limit

The results of Binary regression analysis to determine the effect of 5 independent variables including age, SSD, stone density, stone size and R/L location on ESWL success status are shown in Table 4. This five-variable model explaining ESWL success seemed to be appropriate overall (Omnibus Test, p<0.001 and Hosmer-Lemeshow goodness of fit test, p=0.199). However, except for SSD, stone density and R/L location, the effect of patient age and stone size on ESWL success was statistically insignificant (p>0.05). Therefore, these independent variables were excluded from the model. Binary regression analysis was performed again with a simpler model consisting of SSD, stone density and R/L location (Table 5). This three-independent variable model was found to predict with similar accuracy to the five-independent variable model (79.5% vs. 78.8% overall prediction percentage, respectively). In this model, the effects of the independent variables SSD, stone density and R/L location on ESWL success were statistically significant (p=0.005, p=0.002 and p=0.014, respectively). The formula created with the B coefficients obtained from this simple model can be used to estimate the probability of ESWL success. A probability value >0.5 was considered as success. Euler (e) number: 2.718281.

$$P(Y)=\frac{1}{1+e^{-(B0+Ba*Xa+Bb*Xb+Bc*Xc)}}$$

According to the odds ratios (OR) obtained from the binary logistic regression analysis, a one-unit increase in SSD, stone density, and R/L location decreased the probability of successful ESWL by 0.966, 0.998, and 0.335 times, respectively.

The results of statistical comparisons of the groups, correlation, binary regression and ROC (Receiver operating characteristic) analysis suggest that SSD, stone density and R/L location parameters are closely related to ESWL success and that these parameters can be used independently of each other as predictive markers for predicting ESWL success. Furthermore, when the three parameters SSD, stone density and R/L location were used together, ESWL success could be predicted with an accuracy of approximately 78.8%.

DISCUSSION

This study underscores the potential for decreased ESWL success in patients exhibiting increased stone density, prolonged SSD, and advanced age. These findings emphasize the critical need for a comprehensive assessment of these factors when formulating ESWL treatment plans.

ESWL is a preferred and widely used method for the treatment of ureteral calculi in clinical practice. However, many factors affecting the success of this treatment method are among the difficulties faced by clinicians in treatment planning. For this reason, Guidelines that can be used worldwide have been established. In the literature, there are numerous studies examining the effects of stone size, density, SSD, patient age and urinary parameters on ESWL success (10,13,15,16). Accurate evaluation of these factors plays a critical role in optimizing treatment outcomes. Moreover, ESWL procedure involves certain risks. ESWL exerts a series of mechanical forces on the stones, causing cavitation and fragmentation of the stones. These effects have the potential to cause aseptic inflammation and tissue damage in the kidney and adjacent organs (17). Therefore, comprehensive studies are still needed to predict ESWL success.

In this study, although the study groups were found to be similar in terms of gender and BMI, the fact that the group with failed ESWL treatment was older coincides with the study reporting that the management of elderly patients with urolithiasis is difficult due to the presence of comorbidities (18). However, there are also many studies reporting no relationship between age and ESWL (14,16,19). The possible reason for these different results regarding age may be due to individual differences in the groups, the composition of the stone or differences in ESWL application.

The relationship between stone localization and ESWL success has been discussed for a long time. In this study, ESWL success was tested with the location of the stone in the upper/lower ureter and/or R/L ureter. Despite of the fact that there was no statistical difference between stone location and ESWL success, the fact that the stones tended to be relatively localized on the right in ESWL successful patients was not ignored. This finding reminds us the study that was conducted by Soleimani et al. who pointed out that stone type and location were factors contributing to the success of ESWL (20). Stones can be located anywhere from the kidneys to the urethra. The physiology underlying stone formation is complex and involves many factors. Stone formation most often begins with Randall's plaques, which consist of calcium phosphate deposits in the renal papilla (21,22). Calcium oxalate stones form in the loop of Henle. Kidney stones commonly contain calcium. The rarer Struvite stones are associated with infection. In our study, complete urinalysis parameters and crystals were not associated with ESWL success. However, the lack of chemical analysis of the stones is a shortcoming of the evaluation. Our study results and all this information emphasize that future comprehensive studies should include stone localization and stone analysis. Another indicator of the importance of stone localization was the finding that R/L localization had a significant effect on the prediction of ESWL success in regression analysis.

Previous studies have frequently emphasized the effect of stone density on ESWL treatment outcomes. Anatomic factors such as SSD have also been reported to have a significant effect on the success of ESWL (13,16,23). However, the relationship of urinary components, especially crystal types and other urinary biochemical parameters, with treatment outcomes has been less investigated (13,24,25). In this context, our study aimed to elucidate the role of stone structure, patient characteristics and urine analysis in ESWL success. The most important result of our study was that those who failed ESWL treatment had higher stone density and longer SSD. Moreover, the logistic regression analysis showed that SSD, stone density and R/L localization had significant effects on ESWL success, which supports the previous statistical evaluation. The significant differences in these parameters in terms of ESWL treatment success overlap with the studies of Garg, who independently reported a correlation between shock wave lithotripsy results and stone density, and Doherty, who suggested that the greater the distance between the stone and the skin, the less effective the shock wave emitted by the lithotripter (13,26). Therefore, considering that it is not possible to alter the stone density or the SSD, it is necessary to adjust the shock waves of the ESWL units according to this distance and stone density.

In this study, it was found that those with a stone density <1000 HU had smaller stone size and higher ESWL success, as well as a correlation between stone size and density, which coincides with the finding of Al-Zubi et al. who reported that determination of stone density and stone size before ESWL can be used to predict ESWL success (16). In another study on ESWL success, the importance of factors such as age, stone size, density and SSD were emphasized (13). In line with this, as it is seen in the study by Soleimani et al., the fact that the stone more frequently chooses the upper localization in those who have successful ESWL may be evidence of a relationship between stone localization and ESWL success (20). Another result obtained in this study was that u-COD crystal was more common in the HU <1000 group and u-COM crystal was more common in the HU ≥1000 group. This finding was considered as evidence that the density and crystal content of urine may be associated with stone formation and ESWL success (13,24,25). In this context, knowing the density, size and content of stones before treatment will help to make more accurate predictions of ESWL success. Therefore, using SSD, stone density and R/L location information together will be useful in predicting ESWL success.

Limitations

This cross-sectional study is obtained from retrospective data, so the cause-effect relationship is more limited than cohort studies. Future prospective studies may provide more definitive findings. Although no statistical difference was found between the study groups in terms of BMI and gender, the complaints and comorbidities of the patients were based on the existing records and patient statements. This may limit the generalizability of the results of the study. The inability to fully determine the chemical composition of the fragmented stones has limited the full evaluation of the different factors affecting the success of ESWL. Although chemical analyses of the patient urine were performed, these results may not represent the exact chemical composition of the stone. In addition, the fact that different people performed the urine analyses in the laboratory has the potential to affect the results of the groups.

CONCLUSION

Higher stone density, longer SSD and older age may lead to decreased success of ESWL treatment. This study highlights the importance of evaluating these variables during ESWL treatment planning to predict outcome and optimize patient management.

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REFERENCES

1. Shah J, Whitfield HN. Urolithiasis through the ages. BJU Int [Internet]. 2002;89(8):801–10. Available from: https://doi.org/10.1046/j.1464-410X.2002.02769.x
2. Romero V, Akpinar H, Assimos DG. Kidney stones: a global picture of prevalence, incidence, and associated risk factors. Rev Urol [Internet]. 2010;12(2–3):e86-96.

Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2931286/

3. Stamatelou K, Goldfarb DS. Epidemiology of Kidney Stones. Healthcare [Internet]. 2023 Feb;11(3):424. Available from: https://doi.org/10.3390/healthcare11030424
4. Hyams ES, Matlaga BR. Economic impact of urinary stones. Transl Androl Urol [Internet]. 2014;3(3):278–83. Available from: https://doi.org//10.3978/j.issn.2223-4683.2014.07.02
5. Chewcharat A, Curhan G. Trends in the prevalence of kidney stones in the United States from 2007 to 2016. Urolithiasis [Internet]. 2021 Feb;49(1):27-39. Available from: https://link.springer.com/article/10.1007/s00240-020-01210-w
6. Atan L, Andreoni C, Ortiz V, Silva EK, Pitta R, Atan F, et al. High kidney stone risk in men working in steel industry at hot temperatures. Urology [Internet]. 2005 May;65(5):858-61. Available from: https://www.goldjournal.net/article/S0090-4295(04)01417-7/abstract
7. Singh N, Agarwal S, Sarpal R. Prospective Evaluation of Extracorporeal Shockwave Lithotripsy in Renal and Upper Ureteric Stone Treatment: Clinical Assessment and Results. Cureus [Internet]. 2024 May;16(5):e61102. Available from: https://www.cureus.com/articles/258649-prospective-evaluation-of-extracorporeal-shockwave-lithotripsy-in-renal-and-upper-ureteric-stone-treatment-clinical-assessment-and-results#!/
8. Siener R, Herwig H, Rüdy J, Schaefer RM, Lossin P, Hesse A. Urinary stone composition in Germany: results from 45,783 stone analyses. World J Urol [Internet]. 2022 Jul;40(7):1813-20. Available from: https://doi.org/10.1007/s00345-022-04060-w
9. Manzoor H, Leslie W. S, W. Saikali S. Extracorporeal Shockwave Lithotripsy. In: StatPearls Publishing [Internet]. 2024 Jan. Treasure Island, FL: PubMed; 2024. Available from: https://pubmed.ncbi.nlm.nih.gov/32809722/
10. Williams JC, Gambaro G, Rodgers A, Asplin J, Bonny O, Costa-Bauzá A, et al. Urine and stone analysis for the investigation of the renal stone former: a consensus conference. Urolithiasis [Internet]. 2021 Feb;49(1):1-16. Available from: https://doi.org/10.1007/s00240-020-01217-3
11. Siener R, Buchholz N, Daudon M, Hess B, Knoll T, Osther PJ, et al. Quality Assessment of Urinary Stone Analysis: Results of a Multicenter Study of Laboratories in Europe. Kunze G, editor. PLoS One [Internet]. 2016 Jun;11(6):e0156606. Available from: https://doi.org/10.1371/journal.pone.0156606
12. Türk C, Petřík A, Sarica K, Seitz C, Skolarikos A, Straub M, et al. EAU Guidelines on Interventional Treatment for Urolithiasis. Eur Urol [Internet]. 2016 Mar;69(3):475-82. Available from: https://doi.org/10.1016/j.eururo.2015.07.041
13. Garg M, Johnson H, Lee S min, Rai BP, Somani B, Philip J. Role of Hounsfield Unit in Predicting Outcomes of Shock Wave Lithotripsy for Renal Calculi: Outcomes of a Systematic Review. Curr Urol Rep [Internet]. 2023 Apr;24(4):173-85. Available from: https://doi.org/10.1007/s11934-023-01145-w
14. Shinde S, Al Balushi Y, Hossny M, Jose S, Al Busaidy S. Factors Affecting the Outcome of Extracorporeal Shockwave Lithotripsy in Urinary Stone Treatment. Oman Med J [Internet]. 2018 May;33(3):209-17. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5971054/
15. Tzelves L, Türk C, Skolarikos A. European Association of Urology Urolithiasis Guidelines: Where Are We Going? Eur Urol Focus [Internet]. 2021 Jan;7(1):34-8. Available from: https://www.eu-focus.europeanurology.com/article/S2405-4569(20)30270-4/abstract
16. Al- zubi M, Al Sleibi A, Elayan BM, Al-issawi SZ, Bani-hani M, Alsharei A, et al. The effect of stone and patient characteristics in predicting extra-corporal shock wave lithotripsy success rate: A cross sectional study. Ann Med Surg [Internet]. 2021;70:102829. Available from: https://doi.org/10.1016/j.amsu.2021.102829
17. Gnessin E, Lingeman JE. Bioeffects of Shock Wave Lithotripsy. Urolithiasis Basic Sci Clin Pract [Internet]. 2012 Jan 1 [cited 2024 May 27];327–32. Available from: https://link.springer.com/chapter/10.1007/978-1-4471-4387-1_40

18. Philippou P, Lamrani D, Moraitis K, Wazait H, Masood J, Buchholz N. Shock-wave lithotripsy in the elderly: Safety, efficacy and special considerations. Arab J Urol [Internet]. 2011;9(1):29-33. Available from: https://doi.org/10.1016/j.aju.2011.03.009

19. Ben Khalifa B, Naouar S, Gazzah W, Salem B, El Kamel R. Predictive factors of extracorporeal shock wave lithotripsy success for urinary stones. Tunis Med [Internet]. 2016;94(5):397-400. Available from: https://pubmed.ncbi.nlm.nih.gov/27801492/

20. Soleimani MJ, Shahrokh H, Soraki VV, Fakhar V, Ghaed MA, Narouie B. Investigating ESWL success rate in the treatment of renal and ureteral stones in children. Urologia [Internet]. 2023;90(3):570-5. Available from: https://doi.org/10.1177/03915603231162663

21. Young MJ, Pang KH, Elmussarah M, Hughes PF, Browning AJ, Symons SJ. Acute extracorporeal shockwave lithotripsy for ureteric stones - 7-years' experience from a busy district general hospital. BJU Int [Internet]. 2022;130(5):655-61. Available from: https://doi.org/10.1111/bju.15820

22. Preminger GM, Tiselius HG, Assimos DG, Alken P, Colin Buck A, Gallucci M, et al. 2007 Guideline for the management of ureteral calculi. Eur Urol [Internet]. 2007;52(6):1610-31. Available from: https://doi.org/10.1016/j.juro.2007.09.107

23. Pareek G, Hedican SP, Lee FT, Nakada SY. Shock wave lithotripsy success determined by skin-to-stone distance on computed tomography. Urology [Internet]. 2005;66(5):941-4. Available from: https://doi.org/10.1016/j.urology.2005.05.011

24. Majzoub A, Al-Ani A, Gul T, Kamkoum H, Al-Jalham K. Effect of urine pH on the effectiveness of shock wave lithotripsy: A pilot study. Urol Ann [Internet]. 2016 Jul;8(3):286-90. Available from: https://journals.lww.com/urol/fulltext/2016/08030/effect_of_urine_ph_on_the_effectiveness_of_shock.6.aspx

25. Dretler SP. Special article: calculus breakability--fragility and durility. J Endourol [Internet]. 1994;8(1):1-3. Available from: https://doi.org/10.1089/end.1994.8.1

26. Doherty R. Stone-to-skin distance predicts success of shock-wave lithotripsy for kidney stones. Nat Clin Pract Urol 2006 32 [Internet]. 2006;3(2):64-64. Available from: https://doi.org/10.1038/ncpuro0387